Smart Energy Meter with Flexible Billing and Payment Options*

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Abstract

The manual postpaid energy metering system, which requires manual reading of meters is still employed in power systems worldwide even though it is known to be slow, labour intensive, costly, error-prone and does not allow consumers to accurately estimate their monthly bills. The prepaid metering system, which attempts to address some of the shortcomings of the postpaid metering system is rigid and not suitable for pay-after-use situations. Smart meters enable automatic collection and processing of consumption data, power system monitoring, automated billing, and a two-way information flow, allowing interaction between the supplier and consumer. These functionalities eliminate most of the challenges of traditional, manually read meters and are capable of incorporating both prepaid and postpaid-style billing systems with various usage choices. This paper proposes a multi-featured, all-in-one smart metering system that allows the supplier to monitor and control usage and provides the consumer with the option to choose between prepaid and postpaid metering modes as needed. More importantly, the paper proposes an incentivised mechanism - based on consumer payment record - for granting usage privileges such as postpaid billing option. This is meant to encourage prompt payment of bills, leading to better revenue mobilisation for the supplier and consequently improved service delivery. In addition, real-time consumption, billing and payment information is hosted on a Google Firebase framework and is made available to the consumer through a mobile application. The supplier also accesses the information through a web application. The system is implemented and demonstrated using low-cost, off-the-shelf hardware and freely available open-source software.

Keywords: Electricity, Energy Meter, Smart Meter, Automated Billing

1 Introduction

One of the driving forces behind the development of any nation is electricity. To supply electricity reliably to end-users, the provider needs to be able to accurately measure the quantity supplied (Casarin and Nicollier, 2010). Energy meters provide the means of obtaining this information. Currently, two types of traditional metering systems are available; the pre-payment or prepaid and the post-payment or postpaid energy metering systems. While the postpaid metering technology allows customers to pay for consumption after usage, prepaid consumers pay before use (Khan *et al.,* 2007). A major challenge of the traditional postpaid system includes the need to manually read meters at the end of the billing cycle before billing can be processed (Sualihu and Rahman, 2014; Adusah-Poku and Takeuchi, 2019). Reading meters this way is error-prone and susceptible to deliberate manipulations. Delays or even defaults in bill payment are also common problems with this method (Tuffour *et al.,* 2018). Besides, the system is intrusive and poses security challenges.

With the prepaid system, a consumer pays for energy in advance and are given a recharge card with the purchased credit to load the meter. When this credit is exhausted, power is disconnected. Thus, this system eliminates the need for manual meter reading and ensures improved bill payment. Neither system, however, provides full-duplex communication and interactivity for users (Boadu, 2016).

However, while eliminating some of the prevailing problems of the postpaid metering system, the prepaid system introduces additional problems of its own. Among them are the lack of payment flexibility, the constant need to recharge prepaid cards and the inability of consumers to use energy (Khalid *et al.,* 2019).

Several research studies have proposed techniques to improve energy consumption, billing and revenue collection by utility companies. For example, Sehgal *et al*. (2010) proposed a postpaid energy meter that facilitated automatic billing without human intervention and alerts a consumer how much he or she is supposed to pay. In another study, Jain and Bagree (2011), suggested a prepaid system that acted like a prepaid mobile phone system as an effort towards upgrading existing meters in India. A prepaid card was modelled to be embedded into existing meters. In addition, smart meters enable many other functionalities to be incorporated in electrical measuring systems, including data storage and management, communication capabilities, intrusion and energy theft control, demand-side control, and connectivity with other devices (Avancini *et al*., 2019). Azasoo and Boateng (2012), designed a GSM-based Smart Meter System for real-time generation of bills by a web-based application. The web-based application aided both

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consumers and distribution companies to interact with the meter remotely. Other studies have been conducted by (Ashna and George, 2013; Tariq, 2014; Shinde and Kulkarni 2014; Sudhan *et al.,* 2015 Azila-Gbettor *et al.*, 2015; Malviya, 2013; Rahman *et al.,* 2015) all in a quest to improve the monitoring of energy consumption and collection of energy revenue.

Given that there is a continuous increase in residential, commercial and industrial consumption of electricity, it has become necessary for utility companies to develop better, non-intrusive, and user-friendly techniques to compute energy consumption, invoice bills and ensure these bills are paid at ease (Oyubu and Nwabueze, 2015; Effah and Owusu, 2014).

This study seeks to develop an all-in-one system to allow consumers to switch metering mode they would prefer while ensuring effective revenue collection, energy conservation, remote controlling and monitoring of energy consumption. The proposed system incorporates automated metering; which allows meter reading to be taken remotely, an automated billing system that bills consumers on real-time consumption and a payment system. The proposed system awards points to encourage good customer payment behaviour and automatically disconnect power and switched between modes when necessary.

2 Resources and Methods Used

2.1 Hardware Components

The proposed smart metering system is made of hardware components employed in energy data acquisition, processing and transmission. The essential components are:

(i). Arduino Uno Microcontroller Board;
(ii). ZMPT101B Voltage Sensor;
(iii). SCT013 Current Sensor;
(iv). ESP8266-01 Wi-Fi Module; and
(v). Solid State Relay.

In addition, an AC/DC Power Supply unit and a 1602 LCD Screen are included for a steady power supply for the accessories and displaying energy information.

2.1.1 Arduino Uno Microcontroller Board

The Arduino UNO board is the main component of the proposed system and is used for processing the acquired voltage and current data. The Arduino UNO board comes with a microcontroller based on the Atmega328P and has 14 pins designated as digital inputs and outputs. Some of the pins have alternate functions, such as pulse with modulation (PWM), external interrupts and serial communication utilized here to transmit energy data from the meter to the server. The digital functionality of the input/output pins is used to control the relay that enables automatic connection and disconnection of loads. The device also has 6 analogue input pins, two of which have been used in this work as inputs from the current and voltage sensors.

2.1.2 ZMPT101B Voltage Sensor

The ZMPT101B voltage sensor is the device used in this work for measuring the voltage across the load of the energy consumer (Abubakar *et al.,* 2017). The sensor is made from the ZMPT101B voltage transformer and is suitable for measuring AC low voltages up to 250 V. Its high accuracy and low-cost attributes make it ideal for the proposed system.

2.1.3 SCT013 Current Sensor

The SCT013 current sensor is a split-core current transformer that measures alternating current (AC) un-obtrusively. Its operating current range is between 0 and 100 A. Before connecting to the Arduino's analog input pin, the output signal from the sensor needs to be constrained between 0 V and the Arduino ADC reference voltage of 5 V. Additionally, a burden resistor is connected externally to limit core saturation and ensure reliable operation. The calculated burden resistor for this project is 33 Ω as shown below.

$$SCT013\ no\ of\ turns = 2000$$

$$Arduino\ Analog\ Reference\ Voltae\ (AREF) = 5\ V$$

$$Primary\ Peak\ Current\ \left(I_{priPk}\right) = I_{RMS} \times \sqrt{2} = 100\ A\ \times 1.414 = 141.4\ A$$

$$Secondary\ Peak\ Current\ (I_{secPk}) = \frac{Primary\ Peak\ Current}{No\ of\ Turns}$$

$$Secondary\ Peak\ Current = \frac{142.4\ A}{2000} = 0.0707A$$

For maximum resolution measurement,

$$voltage\ accross\ burdent\ reisostor\ (V_{br}) = \frac{AREF}{2} = 2.5\ V$$

$$Ideal\ burden\ resistance = \frac{V_{br}}{I_{secPk}} = \frac{2.5\ V}{0.0707\ A} = 35.4\ \Omega$$

35Ω resistor is not a common resistor and therefore 33 Ω which is the nearest common resistor is chosen.

2.1.4 ESP8266-01 Wi-Fi Module

The ESP826 is a low-cost, high-performance WiFi module with extensive on-board processing and storage (Rosli *et al.,* 2018) capacity. It's a self-contained system on a chip that includes a TCP/IP protocol stack, WiFi direct Peer-to-Peer (P2P) mode, and a soft Access Point (AP) mode(Habaeb *et al.,* 2016). For interfacing with other sensors and applications, the module provides two general purpose input-output (GPIO) ports.

2.1.5 Solid State Relay

The Industrial Solid State Relay (SSR) is in this work to connect or disconnect the supply of power as needed. The SSR is an ON-OFF switch that is used to control the flow of electrical power employing a small control signal. The device uses semiconductor principles to accomplish switching, rather than mechanical actuation and is, therefore, faster than electromechanical relays and has lower noise and longer service life span (Kuang *et al.,* 2013).

2.2 Circuit Connections and Energy Calculation

The ZMPT101B voltage and the SCT013 current sensors are connected to the microcontroller through its analog input pins. These sensors acquire instantaneous voltage and current values of the electrical load connected. The product of the voltage and current is integrated over time to obtain the energy consumed over the given period. This calculation is shown in Equation (1). The computed energy along with other parameters is transmitted wirelessly through the ESP8266 Wi-Fi module, which is connected to the Arduino board through the UART serial communication interface (RX and TX pins). Fig. 1 shows the connections of the sensors to the microcontroller peripherals.

The active power P drawn by an electrical load over a period T is used to determine the total energy consumed in T. It is the product of the instantaneous voltage $u(t)$ across the load and the current drawn $i(t)$ and is expressed mathematically as

$$P = \frac{1}{T}\int_{t=0}^{T} u(t)i(t)dt \quad (1)$$

The energy E is then determined as the product of the power and time as shown in Equation (2).

$$E = \int_{t=0}^{T} u(t)i(t)dt \quad (2)$$

The active power is absorbed by consumer loads to do useful work and used in domestic energy billing. In the current implementation, the microcontroller determines the consumed energy in kilowatt-hours (kWh) based on the average active power and duration of use. It does this by continuously sampling instantaneous current and voltage inputs from the analog pins connected to the SCT013 current sensor and the ZMPT101B voltage sensor.

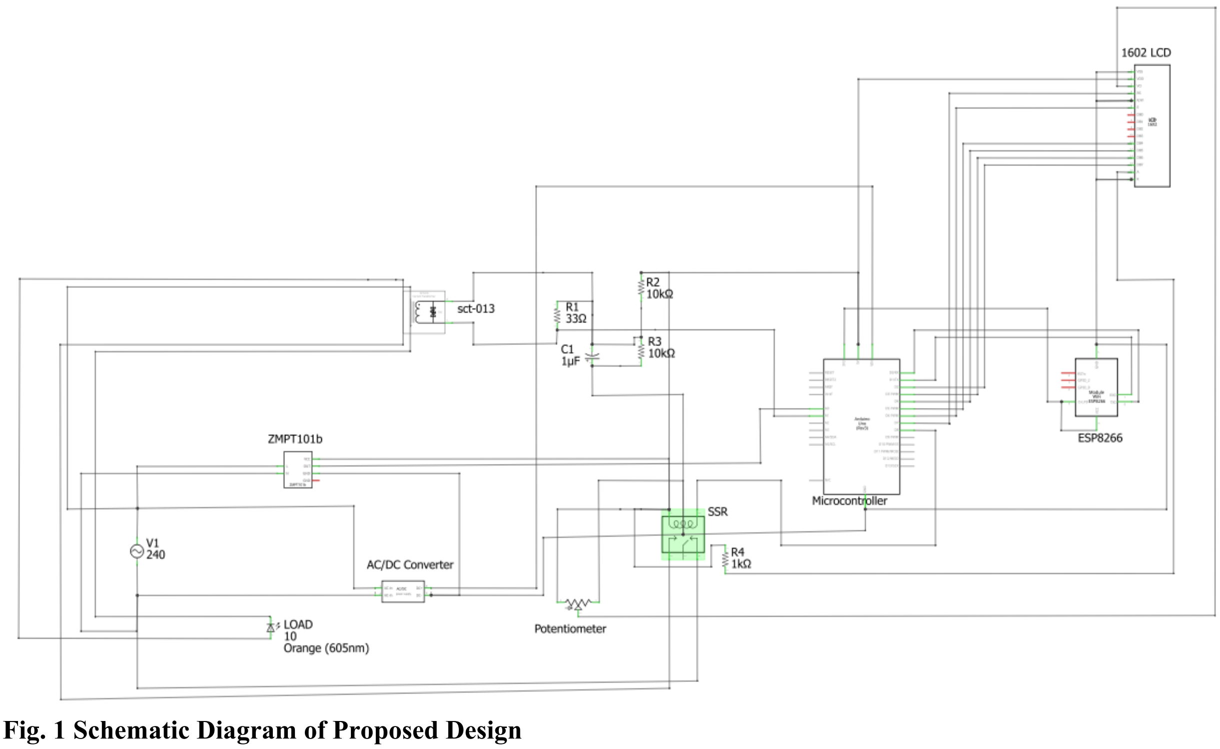

Fig. 1 Schematic Diagram of Proposed Design

The product of the root means square (rms) values of the current and voltage is computed using the discrete-time equivalent of Equation (1), given as Equation (3), to give the average active power in Watts. The product of this power and the elapsed time (in hours) are multiplied and scaled by 1000 units to obtain the energy in kWh.

$$P = \frac{1}{N}\sum_{n=1}^{N} v[n]i[n] \tag{3}$$

where N is the number of samples over which P is computed and $u[n]$ and $i[n]$ are the rms values of the voltage and current, sampled at 2.5 kHz. $u[n]$ and $i[n]$ are given by Equations (4) and (5), respectively.

$$v[n] = \sqrt{\frac{1}{n+1-i_0}\sum_{i=i_0}^{n} v_i^2} \tag{4}$$

$$i[n] = \sqrt{\frac{1}{n+1-i_0}\sum_{i=i_0}^{n} i_i^2} \tag{5}$$

2.3 Software Components

This section describes the front and back end applications that drive all the functionalities of the system. Together, they ensure a secure operation and convenient experience for both the energy provider and consumer.

2.3.1 Android Mobile Application

The android mobile application has been designed to provide an intuitive and easy-to-use interface for energy consumers to monitor, manage and control their energy meters, and also pay their energy bills. The application was developed using Android Studio and Android software development kit (SDK) and Kotlin programming.

The graphical user interface consists of the *meter management* menu, the *make payment* menu, *view consumption* menu, *monitor consumption* menu, *make complaints* menu and *notifications* menu.

The *meter management* menu is designed to help the consumer exploit most of the functionalities of the system, such as switching between consumer modes – prepaid and postpaid.

The *make payment* menu is designed to help consumers make payments of energy bills while the *view consumption* menu is designed to display the consumption data in real-time. *Monitor consumption* menu is to enable consumers to switch on and off of the energy meter and also schedule meter active hours. The *make complain* menu allows consumers to lodge complaints to energy providers while the *notifications* menu displays important notifications on bills, bill payments, the remaining balance for meters running on prepaid, mode switch etc.

2.3.2 The Web Application

The web application is developed to provide energy providers with an easy-to-use interface to manage, monitor and control energy meters remotely.

The web application is developed using ReactJS. ReactJS is a component-based library that is deployed for interactive user interface creation. ReactJS effectively allows for the creation of broad and complex web-based applications that can adjust their data without refreshing the page afterwards. It aims at delivering a better user experience and the development of fast and robust web apps (Aggarwal, 2018).

The web application also allows energy providers to add or register a meter. Apart from the consumer information needed to register a meter, the consumer has to choose a preferred consumer mode; either prepaid or postpaid. The application also aids providers to view individual meter consumption, control the meter remotely and view payment details of consumers.

2.3.3 Google Firebase Real-Time Database

The central point of the system is a Google Firebase real-time database management system. This is where the energy meter, mobile app and web application send and retrieve data in real-time. A real-time database saves and retrieves data on the fly. Data is stored in JSON format and continually synchronized to each associated client. Firebase is Google provided API to create a database and fetch from it in real-time with only a few lines of code (Khedkar *et al.,* 2017). The firebase database is a cloud-based database and does not need SQL-based queries to store or retrieve data.

The energy meters upload their readings to the firebase platform in real-time through the Wi-Fi module and triggers a firebase function that performs the necessary data processing to make energy information available for the end user's mobile app and the utility providers web interface. The mobile application and the web application fetch the updated consumption data from the database each time there is a change in the consumption values.

2.4 System Functions

All of the system functions were handled by Google Cloud Functions (GCF). Google Cloud Functions is a serverless computing or a Function as a Service wherein small units of codes (cloud functions) can be deployed and run on demand (Kijak *et al.*, 2018).

2.4.1 Bill Calculation

GFC was used to implement a function that handles the bill calculations for the system. The function is triggered by the consumed energy value change of the real-time database. The function picks the energy value and calculates the corresponding bill. This makes the billing of consumers real-time. Consumers are billed based on the consumer's tariff category, determined by the type of consumer and total energy consumed over the billing period.

If the meter is running on prepaid mode, the function converts the amount of credit bought into equivalent energy units and credits the consumer's account with these units. On energy value change, the function is triggered and subtracts the energy consumption from the consumer's balance.

2.4.2 Bill Payment and Management

A function to track payment of consumption bills was added using Google Firebase Cloud Functions. This function manages the payment patterns of consumers. For consumers who comply with payment terms, points are awarded to such consumers. The points measure consumers' payment commitment level and are used to provide incentives to consumers and also considered in times where consumers may not be able to pay bills by stipulated deadlines or when prepaid customers would want to move to postpaid mode.

Prepaid Consumers

Taking advantage of Firebase Cloud Messaging (FCM), a function is to trigger as balance gets low to send a notification to prepaid. The notification is to inform consumers they are running out of balance and therefore should top-up in other to prevent power cut at zero balance. When the balance eventually reaches zero, the function sets the status to *out of credit*, indicating that the meter has run out of balance. The automated meter upon fetching this data from the server would trigger the solid-state relay to disconnect the meter from the load. Consumers who consistently maintain a positive balance above a specified threshold are awarded points, which are converted to extra incentives in the form of reduced bills and delayed disconnections in the event of zero balance.

Postpaid Consumers

For consumers who are running on the postpaid mode, the payment due date is set to a particular date as well as the deadline for payment. On the payment due date, the bill is sent to the consumer through the mobile app in the form of a notification and informs the consumer about the payment amount and deadline.

Another function is responsible for managing bill payments from the client-side. On bill payment, this function is triggered to calculate awarded points taking into consideration the number of days left to bill payment deadline for consumers who make full payment of their bills before the deadline is up.
If a consumer pays upfront, before the bill due date, the function compares the amount paid to the average consumption of the consumer, if the amount paid is not less than the average consumption, equivalent points are calculated and awarded to the consumer.

Part Payment of Bill

A consumer who is not able to make full payment is supposed to make an acceptable percentage given by the supplier of the total bill. The acceptable minimum partial payment used in this project is 50% of the total bill. A consumer who makes this acceptable partial payment is given access to power but would however be expected to pay the remaining amount before the next bill due date or make full payment of the following month bill plus the previous balance to be able to have access to power.

Disconnecting Function

If a consumer fails to comply with any of the payment functions explained above, this function calculates the consumer's grace period using the consumer attained points. If a consumer is not able to pay the full amount of the bill before the grace period elapses, the function sets the consumer's status accordingly. The automated meter upon fetching this data from the server triggers the relay to switch the meter off and indicates on its screen that the meter has been switched off due to a default in bill payment.

Reconnection Function

For the consumer to be reconnected, the consumer is required to make full payment of the bill amount. The reconnection function changes the consumer mode to prepaid mode and causes the relay to automatically switch the consumer's load on. The consumer is thereafter supposed to pay upfront before consumption and is expected to maintain a consistently acceptable balance over a period of time before being qualified for switching to postpaid mode.

2.4.3 Changing Billing Mode

For prepaid consumers who wants to change to postpaid mode, the consumer would be expected to have maintained a consistently positive balance for a certain period based on points attained. In that regard, they would be expected to have points that denotes consistent maintenance of positive balance for at least three months to be able to do so. For postpaid consumers who would want to change mode to prepaid mode would be expected to pay off the current bill before the change of mode can be effected.

3 Results and Discussion

The metering, data processing, telecommunication and energy management functionalities of the proposed system were evaluated using test loads – a 23 W energy saving bulb and an HP desktop computer. The following sections show the results of these tests.

3.1 Meter Registration

To enable effective personalised information management, the system requires a one-time meter registration – a process in which meter and customer information is collected and stored in the database. The web application designed for the energy providers was used to register the energy meter as shown in Fig. 2. Some of the information needed included the meter id, billing mode (prepaid or postpaid), the consumer first and last names, contact and residential address and meter category (residential, industrial, or commercial).

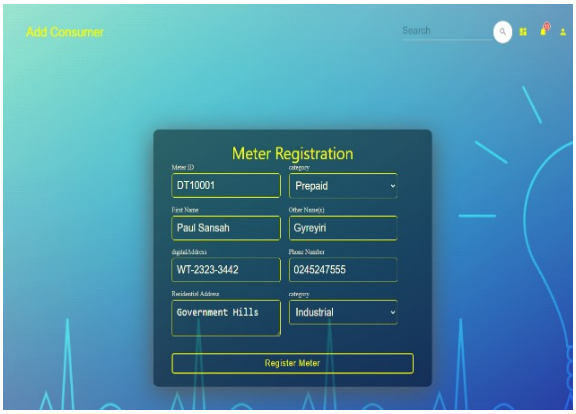

Fig. 2 Web App Meter Registration Interface

3.2 Real-Time Monitoring and System Control

The meter state and consumption information is uploaded onto the firebase real-time database in real-time which can be viewed by the consumer using the designed android mobile application while the energy provider uses the designed web application to monitor and control the consumption of the energy meter as shown in Fig. 3.

Fig. 3 Web App showing Consumption Details of Meter DT10001

The consumer uses the switch meter button to switch the meter on or off. When the consumer switches the meter on with the switch button on the mobile app, a command is sent from the firebase real-time database to switch the meter off, the solid-state relay switches the meter off and displays the action, new status and time. This information can also be viewed by the provider. The controller field is set to two indicating the meter was switched off by the consumer.

The consumer is also able to schedule when the meter is supposed to be switched off or on automatically using the schedule button on the mobile app. Fig. 4 shows the switching off by the switch button and scheduling switch off time using the mobile app while Fig. 5 shows the meter switched subsequently.

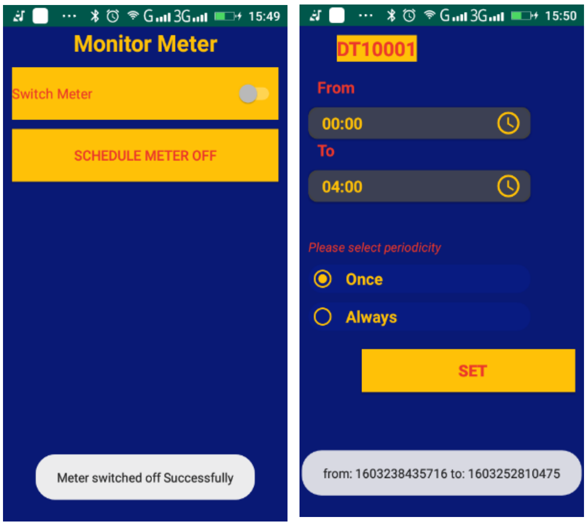

Fig. 4 Instant Switch and Switching Scheduling using Mobile App

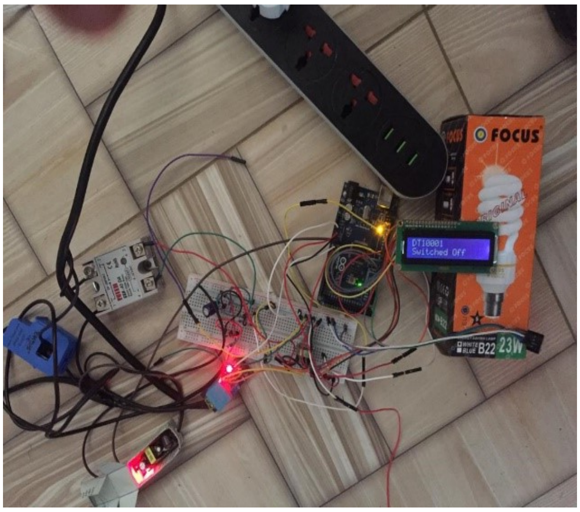

Fig. 5 Meter Switched off By Consumer

3.3 Bill Processing

The bill processing function and the function to check for bill payment were scheduled to run after 24 hours. When the scheduled time for bill processing was due, a push notification was sent to the consumer via the mobile application as shown in Fig. 6 and when clicked on it shows the full notification at the notification screen of the application. The notification also informed the user about the deadline for the payment.

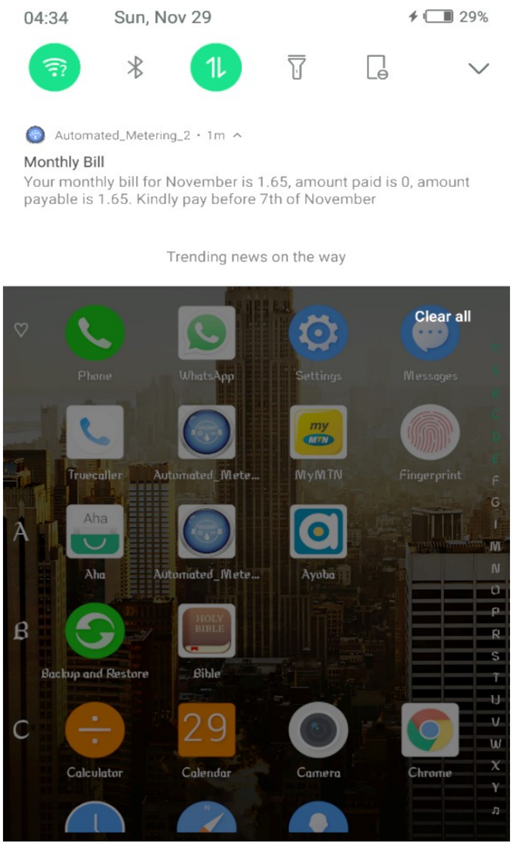

Fig. 6 Monthly Bill Sent to Consumer

3.4 Bill Payment

The mobile app was used to pay for the bill using the MTN mobile money option – a mobile network payment system. For this demonstration, the MTN Sandbox MOMO API was implemented and on successful payment, a notification is sent to the app interface, as shown in Fig. 7, indicating the amount paid and the outstanding balance that needs to be paid to avoid disconnection. In the test case presented, the payment was made before the deadline to assess the user points functionality. As expected, the consumer is notified through notification of the payment and points gained as a result. A total of GHC 2.00 was paid and the system credited the remaining amount to the following month which was December. 8 points were gained. The points are calculated from the number of days left till the given deadline which was 7th December as the payment date was 29th November.

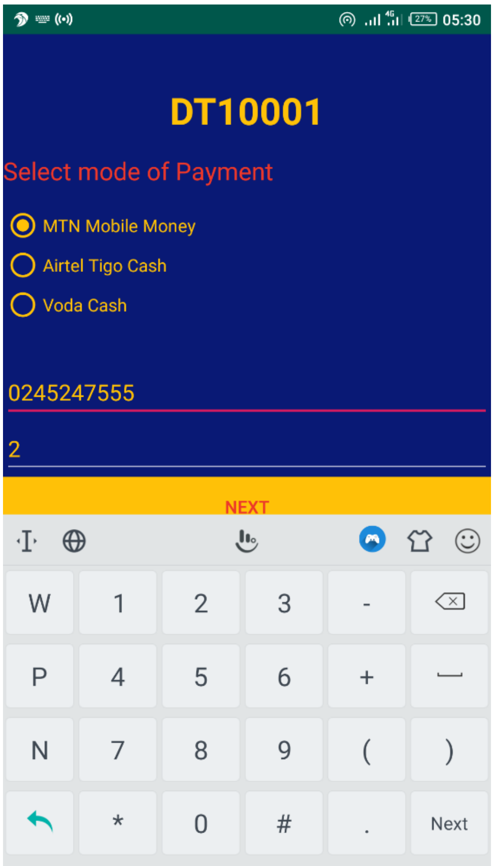

Fig. 7 Bill Payment Using Mobile App

3.4.1 Upfront Bill Payment

An amount that exceeded the average monthly bill was paid upfront before the stipulated time for the next billing was due. The system sent a notification indicating the points awarded to the consumer for paying upfront. The amount paid was GH₵ 2 and the awarded points were 15 as shown in Fig 8.

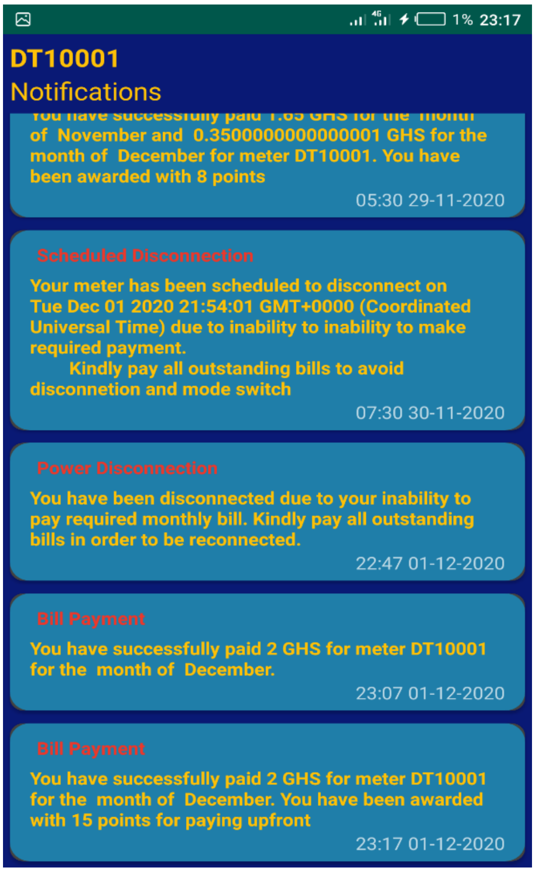

Fig. 8 Notification on Upfront Payment and Awarded Points

3.4.2 Default in Payment

On failing to pay the bill by the stipulated time, the system calculated the disconnection period if the bill was not paid and the consumer was notified through the app. For the test case, the bill was paid before the scheduled time, and as expected, a notification on bill payment was sent and the points were reduced proportionally to the hours it took before the bills were paid.

The above process was repeated but this time, the bill was not paid till the disconnection time, and the meter was switched off automatically and displayed on its screen that the meter is off due to non-payment of bills while a notification was sent through the mobile app.

3.4.3 Bill Settlement and Meter Reconnection

On payment of the outstanding bill, after the meter was switched off, a notification was sent through the mobile application informing the consumer about the payment, power restoration and change of mode of the meter from postpaid to prepaid.

Fig. 9 Notifications of Consumer on Mode Switch

3.4.4 Prepaid Mode

The mobile app was used to buy a credit of GHC 10 and the corresponding energy was calculated and loaded to the user's account followed by a notification of the transaction. The calculated energy was added to the previous balance.

The balanced reduced as energy was consumed. When the balance decreased below a threshold of 10 kWh, a notification was sent to the mobile app informing the consumer about low credit. Another notification was sent on balance reaching less than 5 kWh. The balance was recharged with an amount of GHC 5.00 before the balance run out, notification was then sent to the mobile app indicating a successful recharge and the corresponding points awarded.

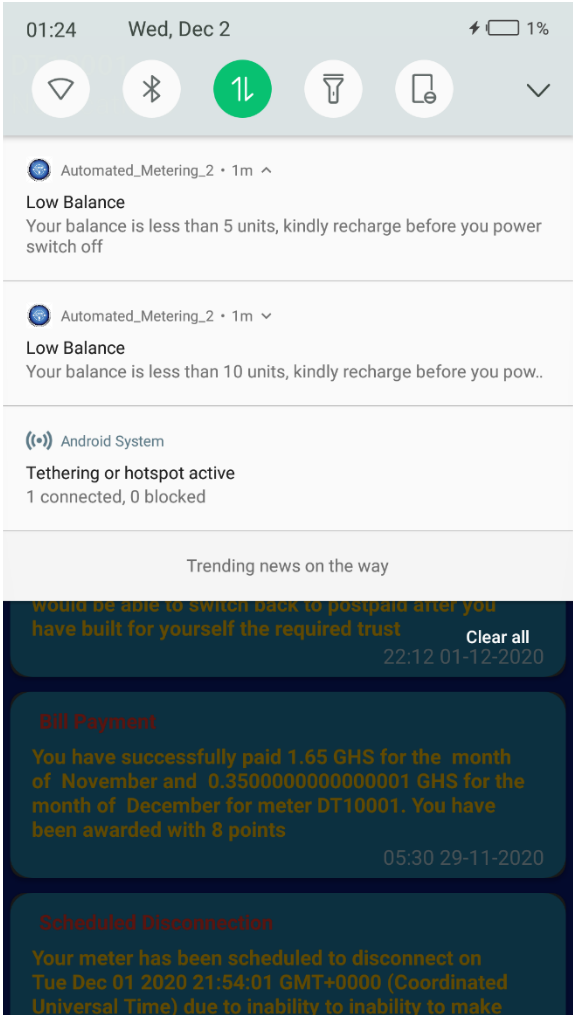

Fig. 10 Push up notification on Low Balance

The meter was allowed to run for some time and notifications on low balance were sent when the balance was less than 10 kWh, 5 kWh and 1 kWh. When the balance reached 0, the status of the meter was set to zero, causing it to switch off the energy meter and a notification was sent to the user through the mobile app informing the consumer to recharge in order to be reconnected to power.

Recharging of Balance after Switch off

The energy was recharged after 4 hours. After successful recharge, it was observed that the points had reduced proportionally to the time it took before the recharge. The 5 awarded points were left with 1 point as shown in Fig 11.

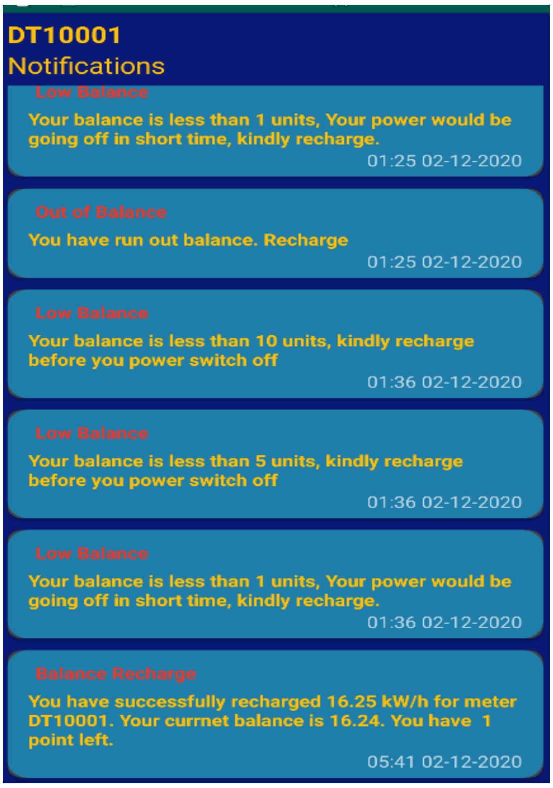

Fig. 11 Notification on Balance Recharge after Meter Reconnection

Changing of Mode

In an attempt to change the metering mode back to postpaid, an alert message was displayed informing the consumer that he does not qualify to change mode until he or she attains at least 30 points. This is depicted in Fig. 12. On attaining the required points, the mode change was successful as shown in Fig 13.

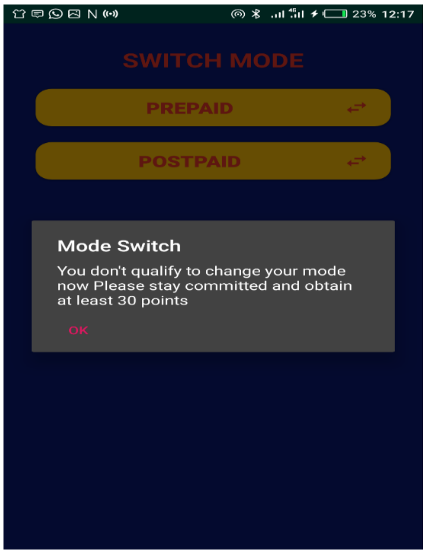

Fig. 12 An Unsuccessful Mode Switch using Mobile App

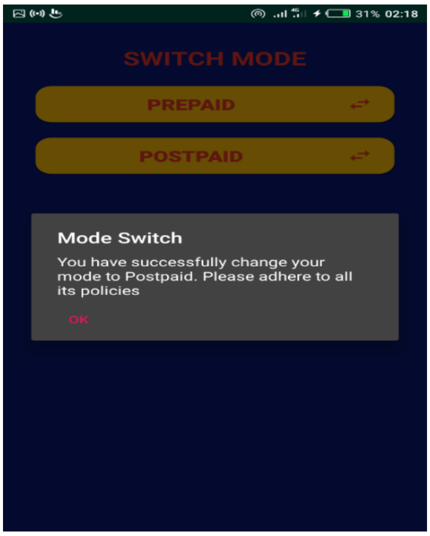

Fig. 13 Successful Mode Switch using Mobile App

The meter was allowed to run for some time and in an attempt to change to prepaid, a toast message informed the consumer to check his current and bill and pay off the bill and make an upfront payment in order to be able to change mode. On paying off the bill and making an upfront payment of GHC 10, the change was possible.

4 Conclusions

This paper proposed a multi-featured postpaid-prepaid system that provides consumers with the option to run on a meter a mode of preference while ensuring effective revenue collection, effective energy management, management of consumer bill payment workflow, monitoring and control of energy infrastructure, automated meter reading, automated billing and balance. To realise these functionalities, an energy meter that stores data on, and communicates with a web server, was implemented.

An android mobile application that enables consumers to view and monitor their energy consumption was designed. The app enables consumers to control the meter remotely and also allow consumers to pay their energy bills or recharge their balance at ease. Also, the web application enables energy providers to read energy consumption, monitor energy consumption and control the energy meter remotely. The effectiveness of the proposed system in consumer-side energy management and control has been demonstrated through a prototype.

References

Abubakar, I., Khalid, S. N., Mustafa, M. W., Shareef, H. and Mustapha, M. (2017), "Calibration of ZMPT101B Voltage Sensor Module Using Polynomial Regression for Accurate Load Monitoring", *Journal of Engineering and Applied Sciences*, Vol. 12, No. 4, pp. 1076 – 1084.

Adusah-Poku, F. and Takeuchi, K. (2019), "Determinants and Welfare Impacts of Rural Electrification in Ghana. Energy for Sustainable Development", *Energy for Sustainable Development*, Vol. 52, pp. 52 – 62.

Aggarwal, S. (2018), "Modern Web-Development Using ReactJS", *International Journal of Recent Research Aspects*, Vol. 5, pp. 133 – 137.

Ashna, K. and George, S. N. (2013), "GSM Based Automatic Energy Meter Reading System with Instant Billing", *In 2013 International Mutli-Conference on Automation, Computing, Communication, Control and Compressed Sensing (iMac4s),* pp. 65 – 72.

Avancini, D. B., Rodrigues, J. J., Martins, S. G., Rabêlo, R. A., Al-Muhtadi, J. and Solic, P. (2019), "Energy Meters Evolution in Smart Grids: A Review, *Journal of Cleaner Production*, Vol. 217, pp. 702 – 715.

Azasoo, J. Q. and Boateng, K. O. (2012), "Smart Metering: A GSM Approach in Ghana", *In 4th International Conference on Adaptive Science & Technology (ICAST),* pp. 158 – 163.

Azila-Gbettor, E. M., Atatsi, E. A. and Deynu, F. (2015), "An Exploratory Study of Effects of Prepaid Metering and Energy Related Behaviour among Ghanaian Household", *International Journal of Sustainable Energy and Environmental Research*, Vol. 4. No. 1, pp. 8 – 21.

Boadu, M. T. B. (2016), "Assessing Customer Satisfaction of Pre-payment Meter Usage in Asokwa District of ECG in Kumasi Metropolis", *Unpublished Doctoral Dissertation*, Kwame Nkrumah University of Science and Technology, 100 pp.

Casarin, A. A. and Nicollier, L. (2010), "Prepaid Meters in Electricity: A Cost-Benefit Analysis", *In P. Marquez, and C. Rufin (Eds.), Private Utilities and Poverty Alleviation: Market Initiatives at the Base of the Pyramid,* Gloucestershire, UK: Edward Elgar Publishing Ltd, pp. 108–133.

Effah, E. and Owusu, K. B. (2014), "Evolution and Efficiencies of Energy Metering Technologies in Ghana", *Global Journal of Research in Engineering,* Vol. 15, No. 6, pp. 35 – 42.

Habaebi, M.H. and Azizan, N.I.N.B., (2016), "Harvesting wifi received signal strength indicator (RSSI) for control/automation system in soho indoor environment with esp8266", *International Conference on Computer and Communication Engineering (ICCCE)* pp. 416-421.

Jain, A. and Bagree, M. (2011), "A Prepaid Meter Using Mobile Communication*", International*

Journal of Engineering, Science and Technology, Vol. 3, No. 3, pp. 160 – 166.

Khalid, M. B. M., Azahari, A. I. B. and Patas, N. H. B. A. (2019), "Energy Meter (E-MON) with IoT Monitoring (Web & Apps)", *Journal on Technical and Vocational Education*, Vol. 4, No. 1, pp. 128 – 137.

Khan, M. F., Zoha, A. and Ali, R. L. (2007), "Design and Implementation of Smart Billing and Automated Meter Reading System for Utility Gas", *In International Conference on Information and Emerging Technologies*, pp. 1 – 6.

Khedkar, S., Thube, S., Estate, W. I. and Naka, C. (2017), "Real-Time Databases for Applications", *International Research Journal of Engineering and Technology (IRJET),* Vol. 4, No. 6, pp. 2078 – 2082.

Kijak, J., Martyna, P., Pawlik, M., Balis, B. and Malawski, M. (2018), "Challenges for scheduling scientific workflows on cloud functions", *2018 IEEE 11th International Conference on Cloud Computing* pp. 460-467.

Kuang, W., Or, S. W., Leung, C. M. and Ho, S. L. (2013), "Development of Piezoelectric Transformer-Coupled Solid State Relays for Electrical Circuit Control in Railway Systems", *International Journal of Rail Transportation*, Vol. 1 No. 1-2, pp. 74 – 86.

Sudhan, R. H., Kumar, M. G., Prakash, A. U., Devi, S. A. N. U. R. and Sathiya, P. (2015), "Arduino ATMEGA-328 Microcontroller", *International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering*, Vol. 3, No. 4, pp. 27 – 29.

Malviya, A. (2013), "An Approach to Automate Power Meter Reading and Billing System", *Global Journal of Management and Business Studies*, Vol. 3, No. 9, pp. 943 – 948.

Oyubu, A. O. and Nwabueze, C. (2015), "Design and Testing of a Smart Energy Metering System Based on GSM Modem", *European Journal of Engineering and Technology*, Vol. 3, No. 4, pp. 35 – 42.

Rahman, M. M., Islam, M. O. and Salakin, M. S. (2015), "Arduino and GSM Based Smart Energy Meter for Advanced Metering and Billing System", *In 2015 International Conference on Electrical Engineering and Information Communication Technology (ICEEICT)*, pp. 1 – 6.

Rosli, R.S., Habaebi, M.H. and Islam, M.R. (2018), "Characteristic analysis of received signal strength indicator from esp8266 wifi transceiver module", *7th International Conference on Computer and Communication Engineering (ICCCE)*, pp.504-507.

Sehgal, V. K., Panda, N., Handa, N. R., Naval, S. and Goel, V. (2010), "Electronic Energy Meter with Instant Billing", *In 4th UKSim European Symposium on Computer Modeling and Simulation*, pp. 27 – 31.

Shinde, M. V. and Kulkarni, P. W. (2014), "Automation of Electricity Billing Process", *In International Conference on Power, Automation and Communication (INPAC)*, pp. 18 – 22.

Sualihu, M. A. and Rahman, M. A. (2014), "Payment Behaviour of Electricity Consumers: Evidence from the Greater Accra Region of Ghana", *Global Business Review*, Vol. 15, No. 3, pp. 477 – 492.

Tariq, T. (2014), "Smart Energy Management in a Smart Environment Using a Mobile Device", *In Global Summit on Computer & Information Technology (GSCIT)*, pp. 1 – 5.

Tuffour, M., Sedegah, D. D., Asante, K. and Bonsu, D. (2018), "The Role of Pre-Paid Meters in Energy Efficiency Promotion: Merits and Demerits in Accra, Ghana", *International Journal of Engineering Trends and Technology (IJETT)*, Vol 60. No. 1, pp. 57 – 64.

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